MANAGING SOILBORNE DISEASES BY MANAGING ROOT MICROBIAL COMMUNITIES

Robert G. Linderman*, USDA-ARS Horticultural Crops Research Laboratory, Corvallis, OR

Soilborne diseases in nurseries have been managed through recent decades by various means. Many approaches have been very successful but were abandoned for reasons of cost or convenience in favor of the more direct approach of applying chemicals such as the broad spectrum soil fumigant methyl bromide. Application of methyl bromide, usually in combination with chloropicrin, gave sure control of diseases and insects, but more importantly of weeds. The expected loss of methyl bromide has prompted the search for alternatives, other chemicals for the short term, and biological or cultural methods for the long term. Except for other chemical fumigants or heat, there will be no single biological treatment that will substitute completely for methyl bromide fumigation. However, many treatments will go a long way toward suppressing soilborne diseases through biological/microbial means. Having those treatments work consistently is the challenge that requires a thorough understanding of how the microbial communities in and on the crop plant roots should function. The major lessons to be learned come from an understanding of microbial communities on roots in undisturbed ecosystems where major diseases rarely occur.

Microbiological stability means maximizing microbial diversity to guarantee that the components of the microbial community on the plant roots is in place and functioning to enhance plant growth and health. For root diseases, this means that the antagonistic potential must be as high as possible in order to kill or suppress pathogens. In most of our cultural systems in nurseries, we have greatly suppressed or eliminated those very microbial populations that we need to be there. We have killed these allies along with the pathogens that needed to be eliminated. Recall the now nearly-forgotten concept of soil pasteurization vs soil sterilization, developed over 50 years ago by K. F. Baker, where disease control was better in soil that had been pasteurized to leave some potential antagonists, than in soil sterilized with live steam that eliminated all microbes, including the antagonists. Without competing antagonists, pathogens have an open road to the roots.

How can we establish the microbial communities needed for stability, growth enhancement, and disease suppression? We must focus on the major players that normally colonize roots and that can influence the growth and health of plants, and without which plants must be treated with high rates of fertilizers and pesticides. For most plants on the earth, that means early establishment of mycorrhizae and their microbial associates. Mycorrhizae can affect root diseases by (a) enhanced nutrition, (b) competition for host photosynthate and infection sites, (c) morphological changes in the roots and root tissues, (d) changes in chemical constituents of plant tissues, (e) reduction of abiotic stresses, and (f) changes in the populations of microbial antagonists in the rhizosphere. When mycorrhizae form, whether ectomycorrhizae on contain-grown or bareroot conifers, or endomycorrhizae on most of the other plants grown in nurseries, great changes take place in the physiology of the roots and the whole plant, and in the soil surrounding the roots, now appropriately called the “mycorrhizosphere”. In this paradigm, the mycorrhizal fungus is the quarterback, and the other associated microbes are the rest of the team. Due to specific changes in the microbial community resulting from altered root exudation plus the specific chemicals exuded by the fungal hyphae that have grown out into the soil, the “team" is ready for action. That action can be to compete with pathogens, increase the availability of nutrients derived from organic substrates, help the plant acquire water and nutrients from well beyond the range of the roots themselves, and reduce other environmental stresses from soil toxicities such as salinity.

We have analyzed the mycorrhizosphere for microbial components that can influence the growth and health of plants. Specifically, we have attempted to quantify the “antagonistic potential” of plants with and without mycorrhizae. When mycorrhizae form, the antagonistic potential of the bacterial community increases significantly compared to that of the non-mycorrhizal plant. Similarly, the diversity of the bacterial community from the background soil increases to levels of detection. But what happens if the diversity of the background soil or soilless growth medium is very low at the outset. Then the “team” of organisms will be weak. If soils have been steamed or fumigated, mycorrhizal fungi and probably many other needed, beneficial associates have been eliminated or their populations greatly reduced. Those populations can only be restored by inoculation at the earliest opportunity in the production system.

Inoculation should be with an established microbial team: with a mycorrhizal fungus quarterback and its teammates of selected microbial associates. In order for the team to be in place when the pathogen and other stresses arrive, seeds or transplants should be inoculated. This gives the microbial team the advantage of prior occupancy. Where biological control has been successful, the antagonist has always been in place to preempt the infection court in order to bar the pathogen. Keep in mind that most pathogens can invade host roots much faster than mycorrhizal fungi, so the microbial team needs to have high antagonistic potential.. This can be accomplished by including in the inoculum known antagonists that can function as the front line while mycorrhizae become established. Studies have shown that most of the known commercial biocontrol agents, whether fungal or bacterial, are fully compatible with mycorrhizae. So the two can be inoculated together. For most nursery crops, except seeded conifers, seed inoculation with a microbial team that includes mycorrhizal fungi is not feasible, largely for mechanical reasons. Seed bacterization has been done with many plants, since bacteria can multiply quickly, and rhizosphere competent strains can follow the roots as they develop. Other microbes, including mycorrhizal fungi, need to be placed beneath the seeds or directly on the roots of transplants in order to become established in time to confront pathogens. While such mixtures of mycorrhizal fungi and microbial associates can be incorporated into the growth medium, it is probably more efficient to place them locally where roots will come in contact quickly and establish the symbiotic relationship as soon as possible. In very porous media, the microbial team inoculum can be drenched into the root zone, thus delivering the microbes where they need to be. But don’t expect to accomplish that once plants are moved up into larger containers. Drenching is not that effective on larger root systems; too many places are “unprotected” against pathogens. After inoculation, cultural practices should be modified, by reducing fertilizer and pesticide applications, in order to favor and maintain the microbial team.

Commercial products are now on the market that can be added to nursery production systems to increase root disease suppression. In these meetings of past years, organic amendments or composts have been shown to suppress diseases by a range of root pathogens. It is assumed that the organic amendments increase the number of antagonists, but that is rarely measured. Composts with antagonists have a more holistic group of microbes, but composts may also be quite variable, and they do not have the whole team together; mycorrhizal fungi are missing. Similarly, adding single microbial antagonist products has suppressed diseases effectively, often as well as chemical treatments, but also those same single “silver bullet” treatments frequently fail. Perhaps the conditions for those microbes to turn on their disease suppressing activities is not right, or conditions are not right for populations to be maintained. In this light, therefore, it seems most appropriate to inoculate plug flats, transplants, or seedbeds with the mycorrhizal team. There are few sources of such microbial teams, but growers should find them and adapt them to their production system. In the short run, this alternative disease control strategy will be less spectacular than using chemical fumigants, but in the long run will provide stable, sustainable disease and crop management.